Extent of Mining Impacts in the Southern Rocky Mountains Ecoregion: Conclusions from the REMAP Data

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ABSTRACT

This summarizes the findings from the 1994-95 Regional Environmental Monitoring and Assessment Program (REMAP) study of the mineralized area within the Southern Rocky Mountains Ecoregion, Colorado. The main objectives were to determine the condition of headwater streams and determine which biological indicators were suitable for detecting the impacts of metals in these streams. Chemical, biological, and physical habitat parameters were sampled in 73 individual sites during the summers of 1994 and 1995. Sites were randomly chosen using a probability design in order to determine the extent of conditions over the entire area. Results of the study conclude that 28% of stream miles in the region are potentially impacted by acid mine drainage; 15% exceeded metals water quality criteria; 31 to 37% were of poor quality as determined by two benthic macroinvertebrate indexes, the Rocky Mountain Biotic Index and the Benthic Index of Biotic Integrity; 11% had sediment and/or water column toxicity and 36% had >50% embedded area. According to this work, the estimated number of stream miles impacted by mining in this region is higher than previous estimates.

INTRODUCTION

This REMAP study focused on the mining belt within the Southern Rockies Ecoregion, an area where impacts to water quality from mining were suspected of being extensive. This was the first use of the EMAP probability design and methods in the Southern Rockies Ecoregion for investigating the extent of contamination from mining. The main objectives of this study were to determine the current condition of the headwater streams in the mineralized area of the Southern Rockies Ecoregion and determine what biological indicators are suitable for detecting the impacts of mining. Previous estimates of the extent of mining-impacted streams in this region ranged from 1240 to 1578 miles (WQCD, 1992; COAIM, 1996).

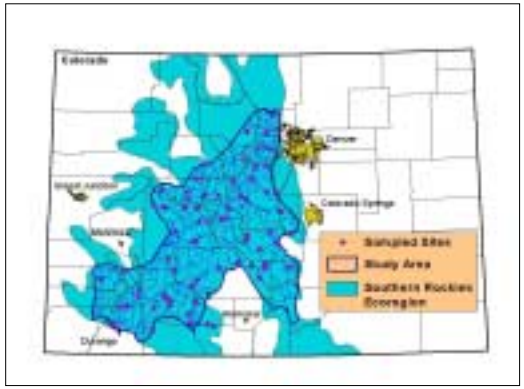
The Southern Rockies Ecoregion (Omernik, 1987) covers approximately 64,000 square miles, spanning from southern Wyoming to northern New Mexico, with the majority located in central Colorado. Within the ecoregion, the mining belt runs generally northeast to southwest. This area was delineated using current and historic mine site locations as defined in a GIS database. This study focused specifically on second, third and fourth order headwater streams.

STUDY DESIGN AND METHODS

A probabilistic sampling design was used, with sites chosen randomly to avoid biases toward good or poor sites (Hughes, et al 1992; Whittier and Paulsen, 1992). In this type of sampling design a small subsample (in this case, stream reaches) is selected out of a larger population (the headwater streams of the Southern Rockies mining belt). Through this design, the condition of the larger population can be estimated with a known confidence level.

The initial target population for this study was 106 sites. After removing dry, non-wadeable, and access-denied sites, 73 were actually sampled (see map below). Of these 73, eight were repeated to determine within and between year variation. The total stream length represented by the 73 sites was 6630 kilometers (4100 miles) out of a total population of 28,800 kilometers (about 17,900 miles) (Hill, et al unpublished). Sampling was performed in the late summer of both 1994 and 1995.

Chemical, biological and physical data were collected at each site. Examples of measures taken are listed in the following chart.



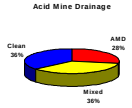
Chemical
Water: Nutrients, Total Solids, Hardness, Sulfate, Chloride, Total and Dissolved Metals, Conductivity, Common Ions, Alkalinity
Sediment: Common Ions, Metals
Biological
Fish, Benthic Macroinvertebrates, Periphyton, Sediment Metabolism, Water and Sediment Toxicity
Physical
Substrate Size, Canopy Cover, Embeddedness, Bank Angle, Depth, Woody Debris, Disturbance, Fish Cover, Discharge, Gradient, Habitat Types, Riparian Vegetation

The amount of stream miles impacted as determined by the various indicators was summed and is reported here. For acid mine drainage, estimates of miles impacted were made based on sulfate concentrations. Exceedances of water quality standards were determined by comparing dissolved metals and hardness values with the Colorado water quality criteria. Fish results were reported directly from the data. For the benthic macroinvertebrate indexes, results of the Rocky Mountain Biotic Index are reported from the literature (Clements, et al 1997) and results of the Benthic-IBI were calculated based on Fore (2000). Water toxicity results were calculated from the data and sediment toxicity results were reported from Lazorchak (1999). Physical habitat results were calculated from the data.

RESULTS

Chemistry

Sites were classified as acid mine drainage impacted, "clean" (no AMD impacts) or with mixed impacts, based on sulfate concentrations (Herlihy, et al 1990). Clean sites were those with sulfate values of less than 100 mg/L. AMD impacted sites were those with sulfate greater than 400 mg/L. By this definition, 28% of stream miles in the mining belt showed signs of acid mine drainage and 36% were not AMD-impacted.



When compared to the Colorado water quality criteria, 15% of stream miles potentially exceeded the acute criteria, chronic criteria, or both, for arsenic, cadmium, copper, lead, selenium, and/or zinc, with zinc the most at 9% of stream miles. Most sites with high concentrations of metals in the water also had high levels in the sediment. There were only a few sites with high sediment metals and low metals levels in the water column, possibly indicating past contamination. Mercury was detected in the sediment at 3 sites (representing 4% of stream miles).

Fish

The fish species diversity in this region is not high, complicating the development of indexes of biotic integrity. However, the presence or absence of fish, especially trout, says something about the condition of streams and provides information regarding general impacts to aquatic systems, but not necessarily specific to mining.

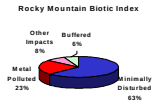
Eighty-one percent of stream miles had at least one trout species present, however only 43% of stream miles had at least one native fish species present. Environmental impacts in this region may need to be high before fish respond well (Herlihy, et al 1998).

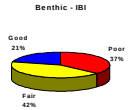
Benthic Macroinvertebrates

A greater taxa richness of macroinvertebrates allowed for more flexibility in creating indexes of biotic integrity (IBI). Two such IBIs were created for this project.

One, the Rocky Mountain Biotic Index (RMBI) (Clements, et al 1997) was based on 13 metrics, including metrics such as total taxa richness, mayfly richness, stonefly richness, % scrapers, % dominance, mayfly abundance, and stonefly abundance. The other, the Benthic-IBI (Fore, 2000), used seven metrics (total taxa (ex. chironomids), mayfly richness, stonefly richness, caddisfly richness, metal intolerant taxa, clinger taxa, and % Heptageniid mayflies).

Each individual metric was scored separately and the individual scores were added to create the total index score. Index scores for each site were then analyzed to determine stream condition (in the case of the Benthic-IBI, scores were divided into poor, fair and good). The RMBI indicated that 63% of streams were minimally disturbed, 23% were metal-polluted, 6% were buffered from metal pollution and 8% were impacted by disturbances other than metals (Clements, et al 1997). In the Benthic-IBI, only 21% of stream miles were rated in good condition, with 42% fair and 37% poor.





Toxicity

This study also featured work not typically done with ambient stream samples - toxicity tests performed in the laboratory with stream water and sediment. The tests measured the survival of *Ceriodaphnia dubia* and *Pimephales promelas* in water, and the survival and growth of *Hyallela azteca* in sediment. Toxicity in water was defined as less than 80% survival, while sediment toxicity was defined as a significant difference from the control.

Almost 7% of stream miles were defined as toxic to either *Ceriodaphnia* and/or fathead minnows with the water column test. A little more than 5% of stream miles were toxic to *Hyallela* using the sediment toxicity test (Lazorchak, 1999). The total amount of stream miles with water and/or sediment toxicity was 11%.

Physical Habitat

Numerous habitat measures were collected in this study, with one especially useful measure highlighted here. While habitat impacts may result from a number of activities, added sedimentation can be one result of mining. One way to detect this impact was by measuring substrate embeddedness. Extensive embeddedness results in the loss of habitat for aquatic insects. This study found that 36% of stream miles had more than 50% embedded area. By way of comparison, 61% of sites rated poor by the B-IBI had more than 50% embeddedness. Generally, the larger the extent of embeddedness, the greater the impact was to benthic macroinvertebrates. The creation of a physical habitat index using the other habitat measures would be useful in determining the full extent of impacts other than mining.

SUMMARY AND CONCLUSIONS

⇒ The number of impacted stream miles was extensive. Potential acid mine drainage was estimated in 28% of stream miles, with toxicity and metals impacts ranging from 11 to 15%. However, the benthic macroinvertebrate indexes detected poor quality in 31-37% of stream miles. Accounting for the fact that natural factors may play a role at some poor-scoring sites, this was still significant (additionally, not all of these impacts were due to mining, with habitat impacts also important). Listed below are the number of miles estimated to be impacted according to each parameter, using the estimate of 17,900 miles of streams in the total population.

Parameter	Impacted Stream Miles
Acid Mine Drainage	5012
Metals	2685
Water/Sediment Toxicity	1969
RMBI (Metal Polluted)	4117
RMBI (All Impacts)	5549
B-IBI (Poor)	6623
>50% Embedded Area	6444

⇒ Past estimates (1240 – 1578 miles) of the extent of mining impacts were lower than the estimates from this study, indicating that the extent of mining impacts may be greater than previously thought.

⇒ Benthic macroinvertebrate indexes revealed a larger universe of impaired streams than the chemistry data. Not all impacts to macroinvertebrates were from mining. However, the macroinvertebrates may also be responding to lower levels of chemical exposures over a longer time frame. With the low fish diversity, macroinvertebrates appear to be the best biological indicator in this ecoregion at this time.

⇒ Additionally, this study showed the value in using a random sampling design for estimating the extent of impacts in this ecoregion for these types of impacts.

REFERENCES

For those interested, a detailed list of references can be provided.

ACKNOWLEDGEMENTS

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